Pesticides

The US Environmental Protection Agency (EPA) defines a pesticide as "any substance or mixture of substances intended for preventing, destroying, repelling, or lessening the damage of any pest". A pesticide may be a chemical substance, biological agent (such as a virus or bacteria), antimicrobial, disinfectant or device used against any pest. Pests include insects, plant pathogens, weeds, mollusks, birds, mammals, fish, nematodes (roundworms) and microbes that compete with humans for food, destroy property, spread or are a vector for disease or are a nuisance. Many pesticides are poisonous to humans.

Types of Pesticides

Bactericides for the control of bacteria
Fungicides for the control of fungi and oomycetes
Herbicides for the control of weeds
Insecticides for the control of insects - these can be Ovicides, Larvicides or Adulticides
Miticides for the control of mites
Molluscicides for the control of slugs and snails
Nematicides for the control of nematodes
Rodenticides for the control of rodents
Virucides for the control of viruses

Pesticides can also be classed as synthetic pesticides or biological pesticides, although the distinction can sometimes blur.

Broad-spectrum pesticides are those that kill an array of species, while narrow-spectrum, or selective pesticides only kill a small group of species. A systemic pesticide moves inside a plant following absorption by the plant. This movement is usually upward (through the xylem) and outward. Increased efficiency may be a result. Systemic insecticides which poison pollen and nectar in the flowers may kill needed pollinators such as bees.

Uses and benefits

Pesticides are used to control organisms which are considered harmful. For example, they are used to kill mosquitoes that can transmit potentially deadly diseases like West Nile virus and malaria. They can also kill bees, wasps or ants that can cause allergic reactions. Insecticides can protect animals, because infestations by parasites such as fleas may cause them illness. Pesticides can prevent sickness in humans that could be caused by moldy food or diseased produce.

Herbicides can prevent accidents by clearing roadside trees and brush, which may block visibility. They can also kill invasive weeds in parks and wilderness areas which may cause environmental damage. Herbicides are commonly applied in ponds and lakes to control algae and plants such as water grasses that can interfere with activities like swimming and fishing and cause the water to look or smell unpleasant.

Uncontrolled pests such as termites and mold can damage structures such as houses. Pesticides are used in grocery stores and food storage facilities to manage rodents and insects that infest food such as grain. Each use of a pesticide carries some associated risk. Proper pesticide use decreases these associated risks to a level deemed acceptable and increases quality of life and protects property and the environment.

Pesticides save farmers money by preventing crop losses to insects and other pests; in the US, farmers get an estimated four-fold return on money they spend on pesticides. In the US, about a quarter of pesticides used are used in houses, yards, parks, golf courses, and swimming pools. About 70% of the pesticides sold in the US are used in agriculture.

In 2006, the World Health Organization—WHO suggested the resumption of the limited use of DDT to fight malaria. They called for the use of DDT to coat the inside walls of houses in areas where mosquitoes are prevalent. WHO's malaria chief, said, "One of the best tools we have against malaria is indoor residual house spraying. Of the dozen insecticides WHO has approved as safe for house spraying, the most effective is DDT." Scientists estimate that DDT and other chemicals in the organophosphate class of pesticides have saved 7 million human lives since 1945 by preventing the transmission of diseases such as malaria, bubonic plague, sleeping sickness, and typhus.

History

Since before 2500 BC, humans have used pesticides to prevent damage to their crops. The first known pesticide was elemental sulfur dusting used in Sumeria about 4,500 years ago. By the 15th century, toxic chemicals such as arsenic, mercury and lead were being applied to crops to kill pests. In the 17th century, nicotine sulfate was extracted from tobacco leaves for use as an insecticide. The 19th century saw the introduction of two more natural pesticides, pyrethrum which is derived from chrysanthemums and rotenone which is derived from the roots of tropical vegetables.

In 1939, Paul Müller discovered that DDT was a very effective insecticide. It quickly became the most widely-used pesticide in the world. However, in the 1960s, it was discovered that DDT was preventing many fish-eating birds from reproducing which was a huge threat to biodiversity. Rachel Carson wrote the best-selling book Silent Spring about biological magnification. DDT is now banned in at least 86 countries, but it is still used in some developing nations to prevent malaria and other tropical diseases by killing mosquitoes and other disease-carrying insects.
In the 1940s manufacturers began to produce large amounts of synthetic pesticides and their use became widespread. Some sources consider the 1940s and 1950s to have been the start of the "pesticide era." Pesticide use has increased 50-fold since 1950 and 2.5 million tons (2.3 million metric tons) of industrial pesticides are now used each year. Seventy-five percent of all pesticides in the world are used in developed countries, but use in developing countries is increasing.

Regulation

In most countries, in order to sell or use a pesticide, it must be approved by a government agency. For example, in the United States, the EPA does so. Complex and costly studies must be conducted to indicate whether the material is effective against the intended pest and safe to use. During the registration process, a label is created which contains directions for the proper use of the material. Based on acute toxicity, pesticides are assigned to a Toxicity Class. Intentional pesticide misuse is illegal worldwide.

Some pesticides are considered too hazardous for sale to the general public and are designated restricted use pesticides. Only certified applicators, who have passed an exam, may purchase or supervise the application of restricted use pesticides. Records of sales and use are required to be maintained and may be audited by government agencies charged with the enforcement of pesticide regulations.

"Read and follow label directions" is a phrase often quoted by extension agents, garden columnists and others teaching about pesticides. This is required by law in countries such as the U.S. Similar laws exist in limited parts of the rest of the world. In the U.S., the Federal Insecticide, Fungicide, and Rodenticide Act of 1972 (FIFRA) set up the current system of pesticide regulations. It was amended somewhat by the Food Quality Protection Act of 1996. Its purpose is to make pesticide manufacture, distribution and use as safe as possible. The most important points for users to understand are these: it is a violation to apply any pesticide in a manner not in accordance with the label for that pesticide, and it is a crime to do so intentionally.

Environmental effects

Use of pesticides can have unintended effects on the environment. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water, bottom sediments, and food. Pesticide contaminates land and water when it escapes from production sites and storage tanks, when it runs off from fields, when it is discarded, when it is sprayed aerially, and when it is sprayed into water to kill algae. The amount of pesticide that migrates from the intended application area is influenced by the particular chemical's properties: its propensity for binding to soil, its vapor pressure, its water solubility, and its resistance to being broken down over time. Factors in the soil, such as its texture, its ability to retain water, and the amount of organic matter contained in it, also affect the amount of pesticide that will leave the area.

Air

Pesticides can contribute to air pollution. Pesticide drift occurs when pesticides suspended in the air as particles are carried by wind to other areas, potentially contaminating them. Pesticides that are applied to crops can volatilize and may be blown by winds into nearby areas, potentially posing a threat to wildlife. Also, droplets of sprayed pesticides or particles from pesticides applied as dusts may travel on the wind to other areas. Farmers can employ a buffer zone around their crop, consisting of empty land or non-crop plants such as evergreen trees to serve as windbreaks and absorb the pesticides, preventing drift into other areas. Such windbreaks are legally required in the Netherlands.

Pesticides that are sprayed onto fields and used to fumigate soil can give off chemicals called volatile organic compounds, which can react with other chemicals and form a pollutant called ozone, accounting for an estimated 6% of the total ozone production.

Water

In the United States, pesticides were found to pollute every stream and over 90% of wells sampled in a study by the US Geological Survey. Pesticide residues have also been found in rain and groundwater. Pesticide impacts on aquatic systems are often studied using a hydrology transport model to study movement and fate of chemicals in rivers and streams. As early as the 1970s quantitative analysis of pesticide runoff was conducted in order to predict amounts of pesticide that would reach surface waters.

There are four major routes through which pesticides reach the water: it may drift outside of the intended area when it is sprayed, it may percolate, or leach, through the soil, it may be carried to the water as runoff, or it may be spilled, for example accidentally or through neglect. Factors that affect a pesticide's ability to contaminate water include its water solubility, the distance from an application site to a body of water, weather, soil type, presence of a growing crop, and the method used to apply the chemical. In the US, the Environmental Protection Agency sets Maximum Contamination Levels, or maximum allowable concentrations for a given pesticide, for certain pesticides in public bodies of water.

Soil

Many of the chemicals used in pesticides are persistent soil contaminants, whose impact may endure for decades and adversely affect soil conservation. The use of pesticides decreases the general biodiversity in the soil. Not using the chemicals results in higher soil quality, with the additional effect that more organic matter in the soil allows for higher water retention. This helps increase yields for farms in drought years, when organic farms have had yields 20-40% higher than their conventional counterparts. A smaller content of organic matter in the soil increases the amount of pesticide that will leave the area of application, because organic matter binds to and helps break down pesticides.

Plants

Nitrogen fixation, which is required for the growth of higher plants, is hindered by pesticides in soil. The insecticides DDT, methyl parathion, and especially pentachlorophenol have been shown to interfere with legume-rhizobium chemical signaling. Reduction of this symbiotic chemical signaling results in reduced nitrogen fixation and thus reduced crop yields. Root nodule formation in these plants saves the world economy $10 billion in synthetic nitrogen fertilizer every year.

Pesticides can kill bees and are strongly implicated in pollinator decline, the loss of species that pollinate plants, including through the mechanism of Colony Collapse Disorder, in which worker bees from a beehive or Western honey bee colony abruptly disappear. Application of pesticides to crops that are in bloom can kill honeybees, which act as pollinators. The USDA and USFWS estimate that US farmers lose at least $200 million a year from reduced crop pollination because pesticides applied to fields eliminate about a fifth of honeybee colonies in the US and harm an additional 15%.

Persistent organic pollutants

Persistent organic pollutants (POPs) are compounds that resist degradation and thus remain in the environment for years. Some pesticides, including aldrin, chlordane, DDT, dieldren, endrin, heptachlor, hexachlorobenzene, mirex, and toxaphene, are considered POPs. POPs have the ability to volatilize and travel great distances through the atmosphere to become deposited in remote regions. The chemicals also have the ability to bioaccumulate and biomagnify, and can bioconcentrate (become more concentrated) up to 70,000 times their original concentrations. POPs may continue to poison non-target organisms in the environment and increase risk to humans by disruption in the endocrine, reproductive, and immune systems; cancer; neurobehavioral disorders, infertility and mutagenic effects, although very little is currently known about these chronic effects. Some POPs have been banned, while others continue to be used.

Animals

Pesticides inflict extremely widespread damage to biota, and many countries have acted to discourage pesticide usage through their Biodiversity Action Plans. Widespread application of pesticides can eliminate food sources that certain types of animals need, causing the animals to relocate, change their diet, or starve. Poisoning from pesticides can travel up the food chain; for example, birds can be harmed when they eat insects and worms that have consumed pesticides. Some pesticides can bioaccumulate, or build up to toxic levels in the bodies of organisms that consume them over time, a phenomenon that impacts species high on the food chain especially hard. The USDA and USFWS estimate that about 20% of the endangered and threatened species in the US are jeopardized by use of pesticides.

Birds

Birds are common examples of non-target organisms that are impacted by pesticide use. Rachel Carson's landmark book Silent Spring dealt with the topic of loss of bird species due to bioaccumulation of pesticides in their tissues. There is evidence that birds are continuing to be harmed by pesticide use. In the farmland of Britain, populations of ten different species of birds have declined by 10 million breeding individuals between 1979 and 1999, a phenomenon thought to have resulted from loss of plant and invertebrate species on which the birds feed. Throughout Europe, 116 species of birds are now threatened. Reductions in bird populations have been found to be associated with times and areas in which pesticides are used. The USDA and USFWS estimate that over 67 million birds are killed by pesticides each year in the US.

Aquatic life

Fish and other aquatic biota may be harmed by pesticide-contaminated water. Pesticide surface runoff into rivers and streams can be highly lethal to aquatic life, sometimes killing all the fish in a particular stream. For example, in Montague P.E.I., nine "fish kills" happened in one year: every fish, snake, and snail was killed in a river called Sutherland's Hole near potato farms from which herbicides, insecticides, and fungicides ran off after heavy rains. Pesticide-related fish kills are frequently unreported and likely underestimated.

Application of herbicides to bodies of water can cause fish kills when the dead plants rot and use up the water's oxygen, suffocating the fish. Some herbicides, such as copper sulfite, that are

applied to water to kill plants are toxic to fish and other water animals at concentrations similar to those used to kill the plants.

Pesticides can accumulate in bodies of water to levels that kill off zooplankton, the main source of food for young fish. The USDA and USFWS estimate that between 6 and 14 million fish are killed by pesticides each year in the US. The faster a given pesticide breaks down in the environment, the less threat it poses to aquatic life. Insecticides are more toxic to aquatic life than herbicides and fungicides.

Amphibians

Some scientists believe that certain common pesticides already exist at levels capable of killing amphibians in California. They warn that the breakdown products of these pesticides can be 10 to 100 times more toxic to amphibians than the original pesticides. Direct contact of sprays of some pesticides (either by drift from nearby applications or accidental or deliberate sprays) can be highly lethal to amphibians.

US scientists have found that some pesticides used in farming disrupt the nervous systems of frogs, and that use of these pesticides is correlated with a decline in the population of frogs in the Sierra Nevada. In the past several decades, decline in amphibian populations has been occurring all over the world, for unexplained reasons which are thought to be varied but of which pesticides may be a part. Being downwind from agricultural land on which pesticides are used has been linked to the decline in population of threatened frog species in California.

In Minnesota, pesticide use has been causally linked to congenital deformities in frogs such as eye, mouth, and limb malformations. Researchers in California found that similar deformities in frogs in the US and Canada may have been caused by breakdown products from pesticides which themselves did not pose a threat.

Pest resistance

An early discovery relating to pesticide use is that pests may eventually evolve to become resistant to chemicals. When sprayed with pesticides, many pests will initially be very susceptible. However, not all pests are killed, and some with slight variations in their genetic makeup are resistant and therefore survive. Through natural selection, the pests may eventually become very resistant to the pesticide.

Pest resistance to a pesticide is commonly managed through pesticide rotation, which involves alternating among pesticide classes with different modes of action to delay the onset of or mitigate existing pest resistance. Tank mixing pesticides is the combination of two or more pesticides with different modes of action in order to improve individual pesticide application results and delay the onset of or mitigate existing pest resistance.

Pest rebound and secondary pest outbreaks

Non-target organisms, organisms that the pesticides are not intended to kill, can be severely impacted by use of the chemicals. In some cases, where a pest insect has some controls from a beneficial predator or parasite, an insecticide application can kill both pest and beneficial populations. A study comparing biological pest control and use of pyrethroid insecticide for

diamondback moths, a major cabbage family insect pest, showed that the insecticide application created a rebounded pest population due to loss of insect predators, whereas the biocontrol did not show the same effect. Likewise, pesticides sprayed in an effort to control adult mosquitoes, may temporarily depress mosquito populations, however they may result in a larger population in the long run by damaging the natural controlling factors. This phenomenon, wherein the population of a pest species rebounds to equal or greater numbers than it had before pesticide use, is called pest resurgence and can be linked to elimination of predators and other natural enemies of the pest.

Loss of predator species can also lead to a related phenomenon called secondary pest outbreaks, an increase in problems from species which were not originally very damaging pests due to loss of their predators or parasites. An estimated third of the 300 most damaging insects in the US were originally secondary pests and only became a major problem after the use of pesticides. In both pest resurgence and secondary pest outbreaks, the natural enemies have been found to be more susceptible to the pesticides than the pests themselves, in some cases causing the pest population to be higher than it was before the use of pesticide

Health effects

Pesticides can present danger to consumers, bystanders, or workers during manufacture, transport, or during and after use. For Farmers, there have been many studies of farmers with the goal of determining the health effects of pesticide exposure. The World Health Organization and the UN Environment Program estimate that each year, 3 million workers in agriculture in the developing world experience severe poisoning from pesticides, about 18,000 of whom die.

Research in Bangladesh suggests that many farmers do not need to apply pesticide to their rice fields, but continue to do so only because the pesticide is paid for by the government. Organophosphate pesticides have increased in use, because they are less damaging to the environment and they are less persistent than organochlorine pesticides. These are associated with acute health problems such as abdominal pain, dizziness, headaches, nausea, vomiting, as well as skin and eye problems. Additionally, many studies have indicated that pesticide exposure is associated with long-term health problems such as respiratory problems, memory disorders, dermatologic conditions, cancer, depression, neurologic deficits, miscarriages, and birth defects. Summaries of peer-reviewed research have examined the link between pesticide exposure and neurologic outcomes and cancer, perhaps the two most significant things resulting in organophosphate-exposed workers.

Consumers

There is concern that pesticides used to control pests on food crops are dangerous to people who consume those foods. These concerns are one reason for the organic food movement. Many food crops, including fruits and vegetables, contain pesticide residues after being washed or peeled (see Pesticide residues in food, below). In the US, levels of residues that remain on foods are limited to tolerance levels that are established by the USEPA and are considered safe. The EPA sets the tolerances based on the toxicity of the pesticide and its break-down products, the amount and frequency of pesticide application, and how much of the pesticide (i.e., the residue) remains in or on food by the time it is marketed and prepared. Tolerance levels are obtained using scientific risk assessments that pesticide manufacturers are required to produce by conducting

toxicological studies, exposure modeling and residue studies before a particular pesticide can be registered, however, the effects are tested for single pesticides, and there is no information on possible synergistic effects of exposure to multiple pesticide traces in the air, food and water.

In the US, the National Academy of Sciences estimates that between 4,000 and 20,000 cases of cancer are caused per year by pesticide residues in food in allowable amounts. A new study conducted by the Harvard School of Public Health in Boston, has discovered a 70% increase in the risk of developing Parkinson's disease for people exposed to even low levels of pesticides. A study published by the United States National Research Council in 1993 determined that for infants and children, the major source of exposure to pesticides is through diet. A study in 2006 measured the levels of organophosphorous pesticide exposure in 23 school children before and after replacing their diet with organic food (food grown without synthetic pesticides). In this study it was found that levels of organophosphorous pesticide exposure dropped dramatically and immediately when the children switched to an organic diet.

Pesticide residues in food

The Pesticide Data Program, a program started by the United States Department of Agriculture is the largest tester of pesticide residues on food sold in the United States. It began in 1990, and has since tested over 60 different types of food for over 400 different types of pesticides - with samples collected close to the point of consumption. Their most recent summary results for pesticides on fruits from the year 2005 are below.

Fresh Fruit and Vegetables	Number of Samples Analyzed	Samples with Residues Detected	Percent of Samples with Detections	Different Pesticides Detected	Different Residues Detected	Total Residue Detections
Apples	774	727	98	33	41	2,619
Lettuce	743	657	88	47	57	1,985
Pears	741	643	87	31	35	1,309
Orange Juice	186	93	50	3	3	94

The public

Exposure routes other than consuming food that contains residues, in particular pesticide drift, are potentially significant to the general public. The Bhopal disaster occurred when a pesticide plant released 40 tons of methyl isocyanate (MIC) gas, intermediate chemical in the production of some pesticides. The disaster immediately killed nearly 3,000 people and ultimately caused at least 15,000 deaths.

Children have been found to be especially susceptible to the harmful effects of pesticides. A number of research studies have found higher instances of brain cancer, leukemia and birth

defects in children with early exposure to pesticides, according to the Natural Resources Defense Council.

Peer-reviewed studies now suggest nuerotoxic effects on developing animals from organophosphate pesticides at legally-tolerable levels, including fewer nerve cells, lower birth weights, and lower cognitive scores. The EPA finished a 10 year review of the organophosphate pesticides following the 1996 Food Quality Protection Act, but did little to account for developmental neurotoxic effects, drawing strong criticism from within the agency and from outside researchers.

Some scientists think that exposure to pesticides in the uterus may have negative effects on a fetus that may manifest as problems such as growth and behavioral disorders or reduced resistance to pesticide toxicity later in life. One study found that use of pesticides may be behind the finding that the rate of birth defects such as missing or very small eyes is twice as high in rural areas as in urban areas. Another study found no connection between eye abnormalities and pesticides. Pyrethrins, insecticides commonly used in common household insect sprays, can cause a potentially deadly condition if breathed in.

Continuing development of pesticides

Pesticide safety education and pesticide applicator regulation are designed to protect the public from pesticide misuse, but do not eliminate all misuse. Reducing the use of pesticides and replacing high risk pesticides is a solution to reducing risks placed on our society from pesticide use. For over 30 years, there has been a trend in the United States and in many other parts of the world to use pesticides in combination with alternative pest controls. Integrated pest management, the use of multiple approaches to control pests, is becoming widespread and has been used with success in countries such as Indonesia, China, Bangladesh, the US, Australia, and Mexico.

IPM attempts to recognize the more widespread impacts of an action on an ecosystem, so that natural balances are not upset. With pesticide regulations that now put a higher priority on reducing the risks of pesticides in the food supply and emphasize environmental protection, old pesticides are being phased out in favor of new reduced risk pesticides. These new pesticides include biological and botanical derivatives and alternatives that are thought to reduce health and environmental risks. Chemical engineers continually develop new pesticides to produce enhancements over previous generations of products. In addition, applicators are being encouraged to consider alternative controls and adopt methods that reduce the use of chemical pesticides. This process is ongoing and is not an immediate solution to the risks of pesticide use.

Pesticides can be created that are targeted to a specific pest's life cycle, which can be more environmentally-friendly. For example, potato cyst nematodes emerge from their protective cysts in response to a chemical excreted by potatoes; they feed on the potatoes and damage the crop. A similar chemical can be applied to fields early, before the potatoes are planted, causing the nematodes to emerge early and starve in the absence of potatoes.

Alternatives

Alternatives to pesticides are available and include methods of cultivation, use of other organisms to kill pests, genetic engineering, and interfering with insect breeding. Cultivation practices include polyculture (growing multiple types of plants), crop rotation, planting crops in areas where the pests that damage them do not live, timing the planting according to when pests will be least problematic, use of trap crops that attract pests away from the real crop. In the US, farmers have had success controlling insects by spraying with hot water at a cost that is about the same as pesticide spraying.

Release of other organisms that fight the pest is another example of an alternative to pesticide use. These organisms can include natural predators or parasites of the pests. Pathogens such as bacteria and viruses which cause disease in the pest species can also be used. Interfering with insects' reproduction can be accomplished by sterilizing males of the target species and releasing them, so that they mate with females but do not produce offspring. This technique was first used on the screwworm fly in 1958 and has since been used with the Mediterranean Fruit Fly, the tsetse fly, and the gypsy moth. However, this can be a costly, time consuming approach that only works on some types of insects.

Some evidence shows that alternatives to pesticides can be equally effective as the use of chemicals. For example, Sweden has halved its use of pesticides with hardly any reduction in crops. In Indonesia, farmers have reduced pesticide use on rice fields by 65% and experienced a 15% crop increase.